PHOTOVOLTAIC DEMONSTRATION PROJECT

FINAL REPORT

DULCE HIGH SCHOOL

PREPARED
FOR THE

United States Department of Energy

UNDER

Cooperative Agreement No. DE-FC4899R810674
Between
United States Department of Energy
And the
Jicarilla Apache Nation

JICARILLA APACHE TRIBAL UTILITY AUTHORITY
BOARD OF DIRECTORS

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J. Richard Olguin, Project Manager

November 7, 2002

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Introduction

The Jicarilla Apache Nation is in Rio Arriba County in North Central New Mexico. The photovoltaic project was installed at the Dulce High School in the town of Dulce. Dulce is in the most northern part of the reservation near the New Mexico/Colorado boundary and can be reached from the New Mexico State Capitol in Santa Fe, hence to the town of Chama along U.S. Highway 84 to the junction of U.S. Highway 64. Dulce is about 12 miles west of the junction along U.S. Highway 64.

Dulce community is in the mountainous part of the Nation with a population of about 4000. No industry exists in the community, however, a few commercial sites do exist such as a motel, restaurants, gas stations, food and liquor stores.

The following governments that play important parts in community affairs are the:

Jicarilla Apache Tribal Council
U.S. Bureau of Indian Affairs Jicarilla Apache Indian Agency
U.S. Indian Health Service Field Health Clinic
Dulce Independent School System

Chronology of Events

On September 23, 1999, a cooperative agreement under the U. S. Department of Energy (DOE) Indian Renewable Energy Program was made between the DOE and the Jicarilla Apache Nation. The agreement was executed by Dennis D. Maez Contracting Officer for the DOE and was accepted by Rodger Vicenti, President for the Nation. The Financial Assistance Award entitled Photovoltaic Demonstration Project (PV Project) from DOE to the Nation under the agreement was for $109,794.00.

The Nation's project was assigned to the Jicarilla Apache Tribal Utility Authority (JATUA) for implementation and construction on April 14, 2000. The Jicarilla Apache Tribal Utility Authority Board of Directors (JATUA Board) under an executive session addressed the PV Project that was inactive from September 1999 through April 14, 2000. The JATUA Board unanimously agreed that it would be best to assign the PV Project to the JATUA Manager. On April 17, 2000 the JATUA Board appointed J. Richard Olguin as the Project Manager.

On June 29, 2000 contract documents for the PV Project were executed between Altair Energy, LLC, 600 Corporate Circle, Golden, Colorado and the JATUA. A notice to proceed on the PV Project was given to Altair Energy on July 5, 2000. Contract work on the PV array construction

started in August 2000 with all installation work completed in August 2000 and the remainder of the contract for PV education materials completed and accepted in December 31, 2000.

PV Array Installation

The photovoltaic array installation shown in Figure 1 was designed and installed by Altair Energy. The PV System array is rated at about 2,400 watts. The data collection started in September 2000 and ended in September 2002. The maximum power generation during the month of May 2002 was 374 kwh and the minimum was 175 kwh in January 2001.

Figure 1 – Photovoltaic Array Note that only three of four arrays are shown in this figure.

The PV system was installed onto the existing school rooftop to minimize vandalism. Prior to installing the PV system the roof structure was checked by structural engineers to assure its integrity to bear the weight of the PV system.

The modules are connected in series to feed the sine wave inverter. The monitoring sensors comprise of an anemometer, pyranometer and a thermister. The anemometer measures wind speed. The pyranometer measures the solar radiation and the thermister measures the ambient air temperature.

Monthly charted data are shown starting with Graphs-1 through Graph-16 for the third quarter of fiscal year 2002. For the entire two-year project, similar graphs were developed and studied by the Dulce School students.

PV System Specifications

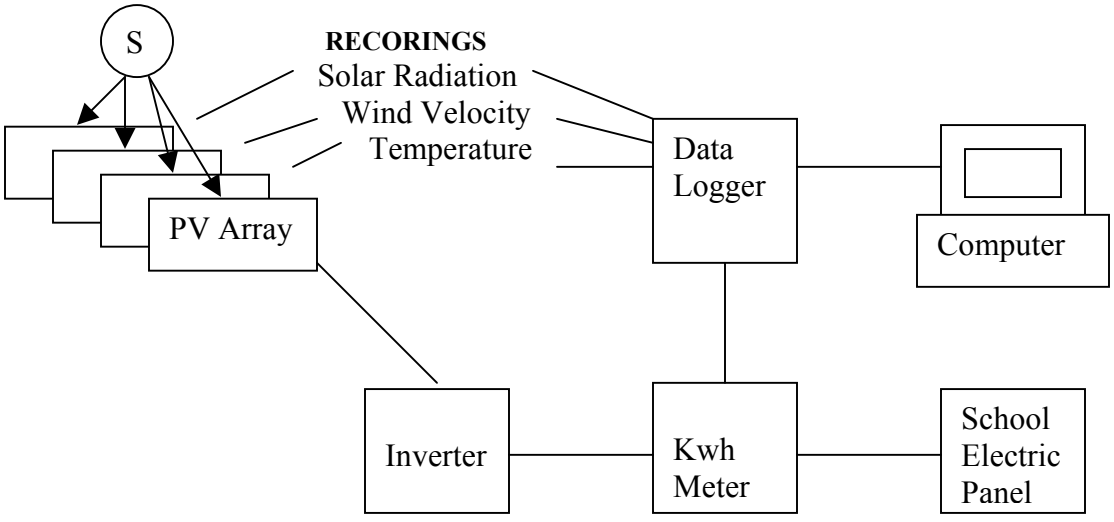
The PV system consists of 32 PV modules mounted onto four racks. The DC electricity generated is converted to high quality AC electricity that supplies the PV system components, computer and all excess electricity into the electricity supply within the school building. The installed system specifications are as follows:

1.	PV make/model:	Astropower AP75
2.	PV module watts:	75
3.	Number of modules:	32
4.	Number of panels	4
5.	No. modules/panel	8
6.	Panel dimensions:	4 ft x 14 ft
7.	Array size	2400 watts
8.	Array tilt	35 degrees
9.	Inverter make/model	Omnion 2.2-6-DID

The photovoltaic project installation included an owner's manual containing detailed information on the PV System.

Refer to Figure 2 for an installation schematic. Also, refer to Figures 6 through 10 starting on page 9 for pictures taken during the PV System installation.

Figure 2 Schematic of the PV System



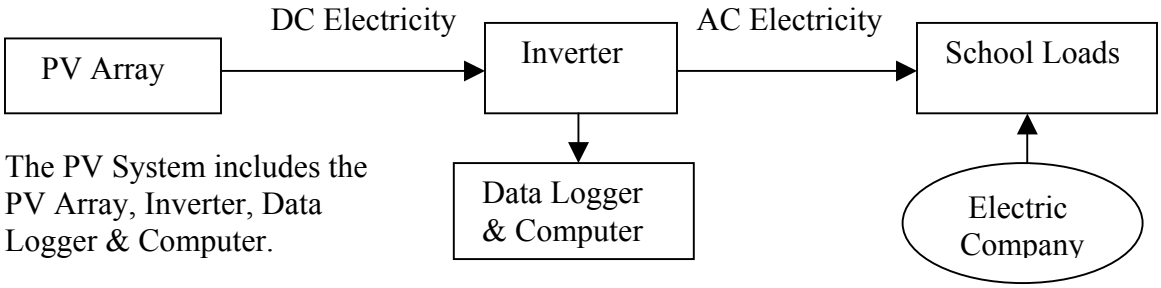
(PV System installation continued from above)

PV Array - Converts sunshine to DC electricity.
Data Logger – Collects and records the solar radiation, wind velocity and temperature.
Inverter - Converts DC electricity to AC electricity.
Computer – Displays and stores collected data.
School Electric Panel – Controls electricity flow from the Electric Company's power grid.

Modes of Operation
Note that no actual monetary transactions took place

Figure 3

Mode 1 Daytime Buying of Electricity

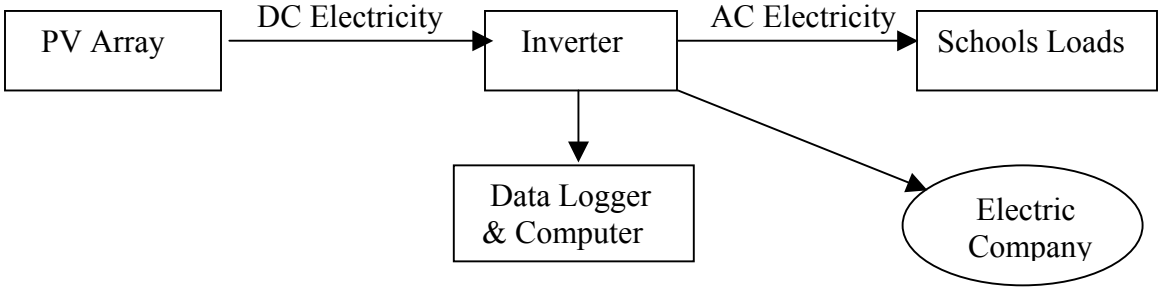


The PV System includes the PV Array, Inverter, Data Logger & Computer.

In Mode – 1 operation, the PV Array generates DC electricity that travels to the inverter that converts the DC electricity to AC electricity that travels to the data logger and computer. Excess electricity travels to the School electrical system to operate lighting and machinery.

Figure 4

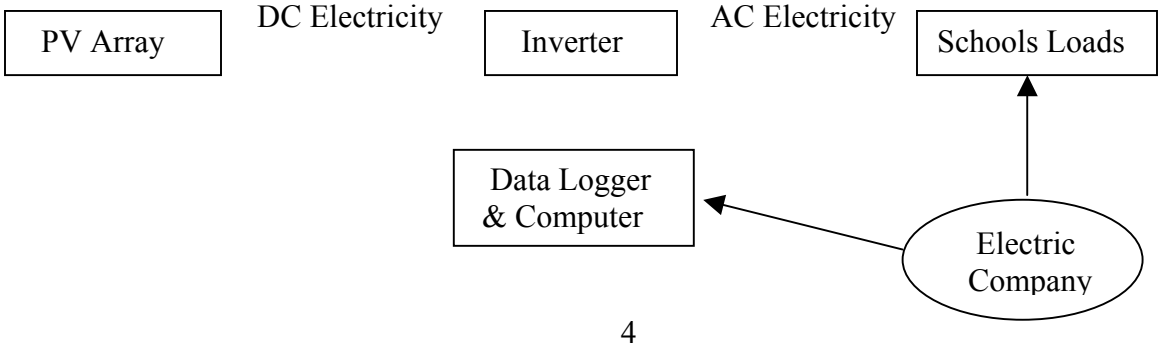
Mode 2 Daytime Selling



In this mode electricity is purchased by the Electric Company and School.

Figure 5

Mode 3 Nighttime Buying



In this mode, during nighttime hours there is no power generation by the PV Array.

Mode 4 Electric Power Outage

In this mode, all systems have no electricity generation for operations. This case will be true for the PV Array if, the power outage occurs during nighttime. If, power outage occurs during the day, Mode 2 will occur.

Goal for the PV System Installation

The primary goal for the PV System installation was to educate Dulce school students, the Jicarilla Apache tribe and other New Mexico tribes on the benefits of renewable energy and energy efficiency. Along with the PV installation, PV educational materials, support for teachers and a two-year PV performance monitoring by students was provided. The PV system also provided on and off reservation renewable energy, energy efficiency education and out reach.

Teacher Training

To start the project education program, an Altair Energy representative conducted teacher training for the installed solar energy collection photovoltaic system to serve the Dulce School's students and facility. The Project Manager and following category of teaching professionals attended a 3.5 hour in-house seminar:

School Principal
Science Teachers (2)
Mathematics Teacher
Computer Training Teacher

The following topics were presented:

Photovoltaic Overview
1. What is Photovoltaics (PV)
2. Benefits of PV
3. How is PV used

The Schools PV System
1. School PV System tour
2. School system specifications
3. Data acquisition system
4. Operation modes
5. Emergency shutdown procedure
6. Scheduled maintenance

PV Education

1. How to use the monitoring program
2. How to down-load and manipulate archived data
3. PV Resource Guide

PV Basics

1. PV history
2. Solar isolation
3. PV technologies
4. Types of modules
5. IV curves
6. Conversion efficiency
7. Maximizing solar resource

The Representative gave detailed descriptions of the PV System components installation and presented a commendable training program with visual aids and material handouts. Interaction was provided by all in session along with a tour of the Photovoltaic System.

PV Student Education Agreement

A professional teaching services agreement was drawn by the JATUA Manager and made effective on November 6, 2000 between the JATUA and Dulce Independent Schools (Dulce Schools.)

Description of Teaching Services Agreement

The Dulce Schools provided the following services:

1. Assigned one or more teachers to supervise students to monitor the PV System.
2. Assigned one or more teachers to teach the basics of solar photovoltaic electric generation and benefits using teaching materials developed by Altair Energy.
3. Assigned one prime teacher and an alternate to supervise students in the collection of data generated by the data logger via the installed computer.
4. Assigned one teacher to be responsible for monthly report generation and development of student activities, interest, comprehension, citing any concepts or projects the students came up with, and to assure that teaching materials were used as developed and provided by Altair Energy.
5. Electronic mailed fiscal year quarterly data recordings from the data logger and computer.

Student Education

Students during the 2000 – 2001 school year were in the Integrated Science course whose education program included the PV System panels and its components. Initial questions asked by students were in part – How much would it cost to install a PV system similar to the Dulce Schools PV System? What possible science project could one do using the PV System? Could a

PV system be used to water live stock out in the ranges where no electric power is now available?

There were 14 students enrolled in the Dulce Schools PV education program and about the same number of students returned for school year 2001 – 2002.

Eighteen students in the Integrated Science course addressed alternative energy sources for the planet that also lead to research on the world wide web for history relative to solar energy as an energy source. This lead to the understanding of what a PV system does and identified its components. Also, understanding terminologies such as photons, electrons, inverters, AC electricity and DC electricity was very helpful. Articles were read about the use of PV in other parts of the world. Lessons were given on how to calculate the efficiency of solar power, and retrieving data from the computer and using it to determine power output, comparison of irradiance versus power output, etc. Assignments were extracted from the Jicarilla Apache Photovoltaic Book provided to the students through the PV Project.

All information and data used and learned were applied toward a final project. Each student designed a solar powered vehicle. The criteria for the design were given, such as vehicle design, gear ratio, amount of power needed for the vehicle to travel a certain distance in a certain amount of time. A seventh grade student did a science fair project using the PV System data to determine the efficiency of solar power. The student compared the advantages of solar power versus fossil fuel burning.

The lessons ended successfully with student suggestions to design other solar powered equipment such as solar powered well pumping, designing a contraption using all types of energy sources and observing the solar array and data tracking/recording equipment working realistically in their community. In the future, students will try to work with the Game & Fish Department and make field trips to other locations that have solar panels installed.

Public Education

A public seminar to inform the local general public and businesses was staged and presented at the Best Western Jicarilla Inn in Dulce. The Project Manager gave presentations using information provided by Altair Energy. A presentation format similar the teacher training session was presented.

PV System Power Generation

Month/Year	2000	2001	2002	Subtotal
January		698	842	1,540
February		908	1,140	2,048
March		1,065	1,335	2,400
April		1,204	1,358	2,562
May		1,403	1,499	2,902
June		1,452	1,310	2,762

July		699	1,189	1,888
August			1,246	1,246
September	1,283		1,126	2409
October	992	1,188	1,087	3,267
November	778	835		1,613
December		819		819
Total Kilowatts	3,053	10,271	12,132	25,456

Dulce High Schools Total Power Needed

Total kilowatt hours generated by the PV System for a 23 non-contiguous month period is about 6,365 Kwh. Dulce School's power need from the power grid for 23 non-continuous months is 624,448 Kwh for 1.92 years. See Table 3.

Power use from the PV System for the computer and printer is about 320.08 kw assuming the computer monitor is on continuously for 24 hours and the printer is used for about 5 minutes per day. Also, note that the PV System equipment requires power input, however, a very minimal amount. To adjust for PV System "other equipment" power need, say 400 kw or 0.400 kw.

Power Cost and Savings Calculations for the Dulce High School (For a 23 non-contiguous month period)

Power need for the PV System = 0.4 kwh/day x 700.8 days = 280 Kwh
Power cost to PV System = $0.00 to provide the required kilowatt hours.

PV System power generation:	6,365 Kwh
PV System power need for computer and other equipment:	-280 Kwh
PV System excess power:	6,085 Kwh
Dulce Schools power need from the electric company grid:	638,566 Kwh
PV System excess power:	-6,085 Kwh
Dulce Schools remaining power need from the grid:	632,481Kwh

Savings Potential

Cost before deduction of PV System excess power:	638,566 Kwh x $0.08 =	$51,085
Cost after deduction of PV System excess power:	632,481 Kwh x $0.08 =	$50,599
Savings potential from PV System excess power:		**$487**

Annual Savings Potential was about $250.

Project Cost by Level of Effort for the 2.4 KW PV System:

- PV Hardware - $22,217
- PV Installation - $7,500
- PV Data System - $6,072
- Education Support - $19,000
- Total - $54,789

Problems Encountered

The call for data from the PV System in October 2001 showed missing data for the last part of July and the entire months of August and September. This problem was discussed amongst the teacher in charge of the school PV education program, Altair Energy and the Project Manager. A copy of available data was delivered to Altair Energy engineering for their evaluation and cause of the problem. Altair Energy, after review of submitted available data and interviews with all concerned, suggested the possibility of the computer system being turned off and that all data recorded in the data logger was lost. A determination was made that about mid July the PV System was turned off possibly by school maintenance crews during annual cleanup/repairs and remained turned off through September 25 when school attendance went back into session. To prevent the PV System turnoff and loss of data, it was suggested that the entire recording system be under lock and key during times of no attendance by students and teacher in charge.

In January, February and March 2002, human errors in properly downloading data from the PV Station computer prevented timely delivery of data to the Project Manager to meet report timelines. Several telephone discussions were made with the Dulce Schools Manager and teacher in charge for the PV Project regarding data delivery. The out-come, a resident computer technician rendered assistance for the computer downloads and data submittals to the Project Manager via electronic mail.

Construction Picture Documentations

Figure – 6 Hoisting PV System material atop the Dulce High School roof.

Figure – 7 PV System panels being lifted for placement onto the Dulce High School rooftop.

Figure – 8 Assembling racks on the Dulce High School rooftop. Concrete blocks will hold down the entire panel assembly. Four racks were assembled. The rack shown to the right is a complete assembly.

Figure – 9 Three panels of the completed PV Array are shown. The entire PV System was assembled in one day. A permit to modify the existing Dulce High Schools electrical panel was secured by Backus Electrical of Santa Fe, New Mexico.

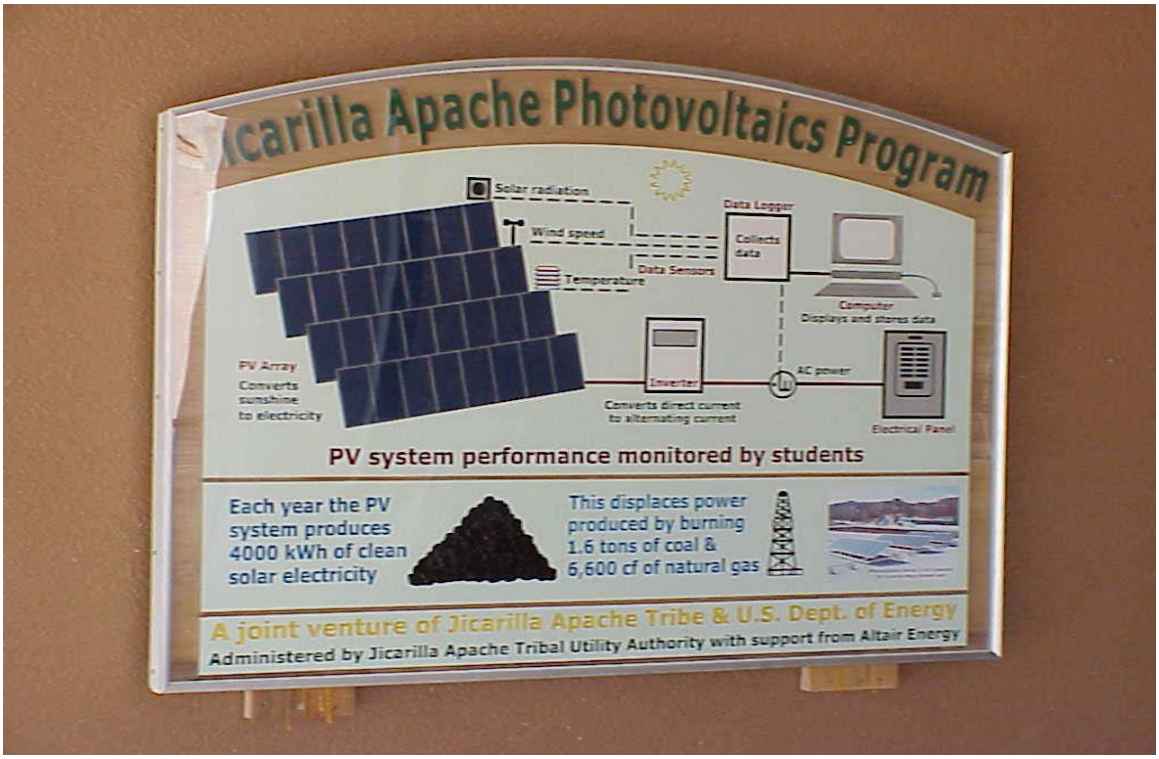


Figure – 10 PV Project information signage posted in the Dulce High School entry.

JICARILLA APACHE TRIBAL UTILITY AUTHORITY
Dulce Independent Schools Power Use Billings

Dulce Indendent Schools Electric Billings
October 1999 through September 2000
Calculations for Western Area Power Association Power Use Verification

Month	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Subtotal**
Elementary School	$1,977.86	$2,482.94	$2,420.42	$2,275.94	$1,117.46	$3,243.26	$2,098.70	$2,213.30	$1,926.99	$1,394.78	$868.08	$603.56	**$22,623.29**
Admin Bldg	$312.44	$355.28	$375.80	$364.88	$394.00	$351.64	$346.68	$534.36	$351.81	$300.68	$307.03	$301.52	**$4,296.12**
Football Fied	$964.85	$961.03	$30.90	$30.81	$33.18	$30.13	$30.49	$45.42	$35.67	$31.58	$29.99	$113.75	**$2,337.80**
Spec Ed	$98.81	$148.47	$134.88	$145.86	$162.78	$122.46	$131.55	$142.53	$98.61	$67.11	$57.13	$48.12	**$1,358.31**
Portable	$29.28	$32.55	$39.39	$45.24	$43.89	$29.04	$41.37	$36.87	$27.27	$22.38	$22.44	$28.25	**$397.97**
Street Lights	$192.41	$204.35	$204.35	$204.35	$204.35	$204.35	$204.35	$204.35	$210.79	$204.35	$193.52	$149.50	**$2,381.02**
Portable Bldg	$94.39	$149.73	$125.79	$122.01	$139.59	$64.92	$89.34	$84.48	$111.80	$96.36	$85.59	$101.46	**$1,265.46**
Vo Ag	$76.20	$144.60	$151.80	$195.00	$209.40	$180.60	$173.40	$209.40	$158.40	$65.40	$28.67	$42.60	**$1,635.47**
Gym	$657.60	$954.60	$889.80	$1,138.20	$241.80	$2,191.60	$781.80	$1,030.20	$616.62	$403.80	$312.41	$337.92	**$9,556.35**
High School	$1,773.02	$2,531.12	$2,446.52	$2,603.39	$2,828.96	$2,563.16	$2,733.41	$2,320.16	$2,270.04	$1,773.62	$1,248.15	$972.38	**$26,063.93**
Chicken Barn	$15.00	$15.00	$15.00	$15.00	$15.00	$15.27	$15.00	$15.09	$15.47	$15.00	$15.00	$15.00	**$180.83**
Rec Bldg	$53.59	$67.92	$58.56	$63.96	$70.62	$59.55	$56.49	$64.59	$48.90	$26.16	$17.99	$17.69	**$606.02**
Bus Garage	$25.79	$128.49	$105.72	$143.43	$238.92	$141.81	$88.80	$98.34	$121.53	$51.54	$39.70	$56.95	**$1,241.02**
Concession Stand	$161.20	$202.11	$151.71	$170.16	$205.44	$126.15	$148.02	$138.21	$128.54	$121.56	$104.31	$126.64	**$1,784.05**
Column Totals	**$6,432.44**	**$8,378.19**	**$7,150.64**	**$7,518.23**	**$5,905.39**	**$9,323.94**	**$6,939.40**	**$7,137.30**	**$6,122.44**	**$4,574.32**	**$3,330.01**	**$2,915.34**	**$75,727.64**

Average cost per month $6,310.64 /month
Using this average for 12 months then equals $75,727.64 /year

Say the average cost per KwH is $0.08, then the number of KwH is **946,595.5 KwH/year** Dulce High **325,799** KwH/year

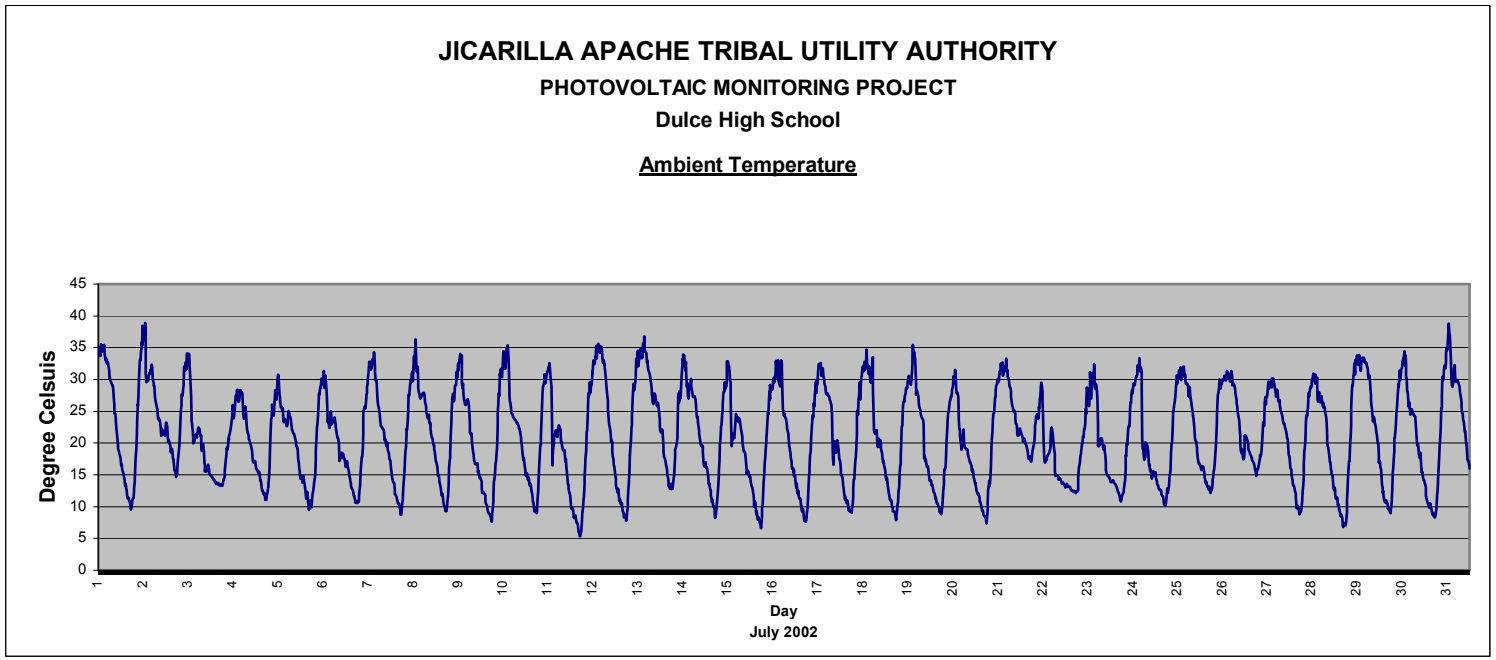
To calculate the number of Kw is

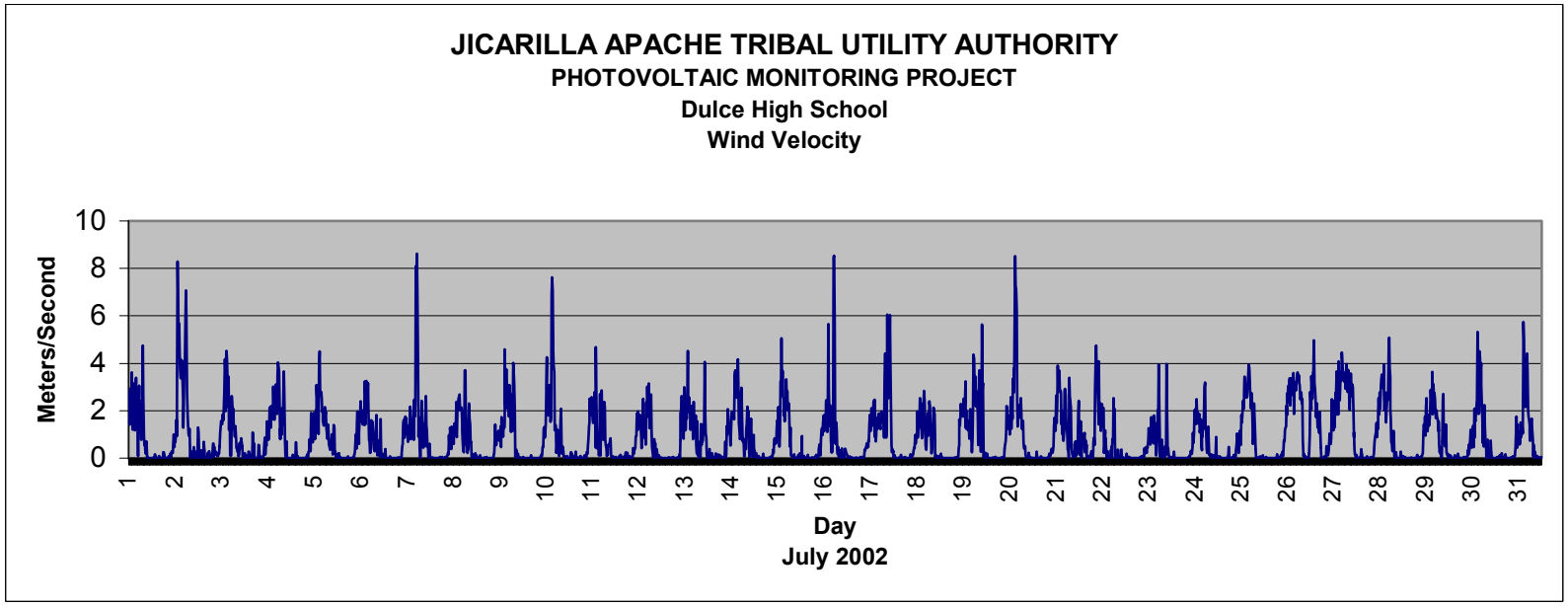
1. Average Load Factor (LF) is 80.1%
2. Average Total Billing Hours (H) is 730 H/y

3. Kw = (KwH/yr)/avg LF x avg H/yr 1,618.86 Kw Dulce High **557 KwH/year**

NOTE
Billing information provided by the Dulce Independent Schools' Administration Office.
Average load factor calculated from information provided by NORA.
Average total billing calculated based on monthly billing time.

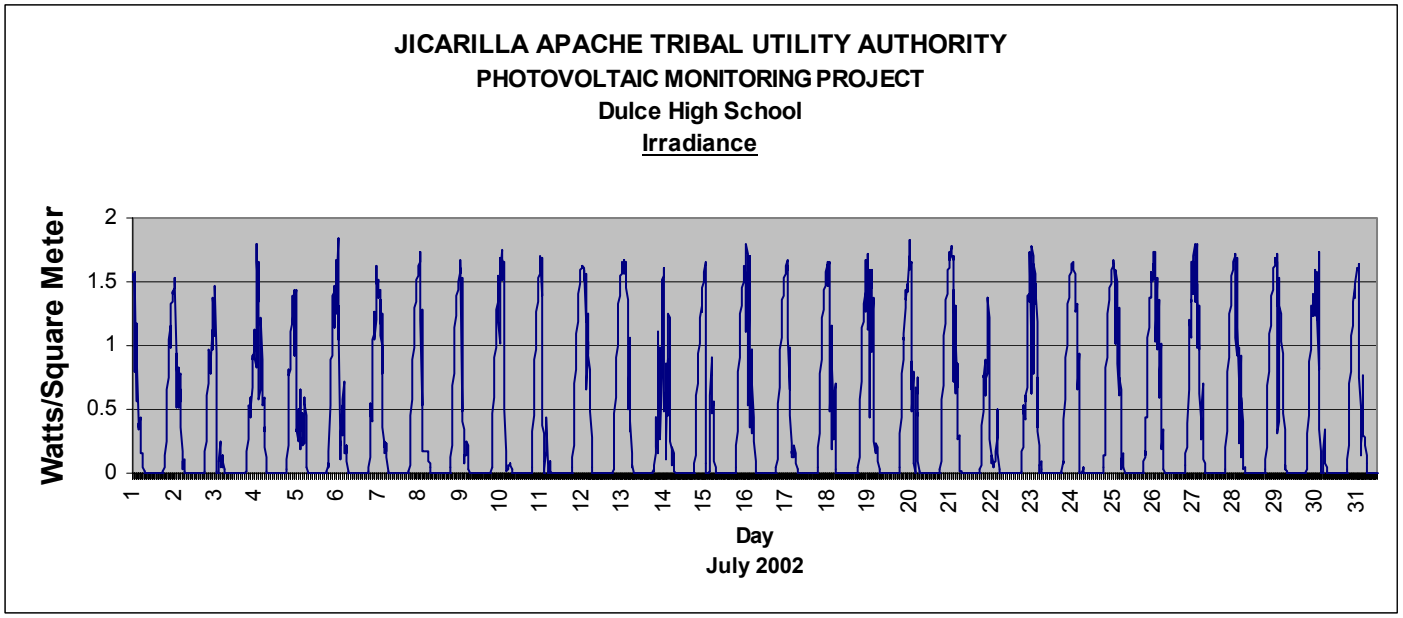
Graph -1

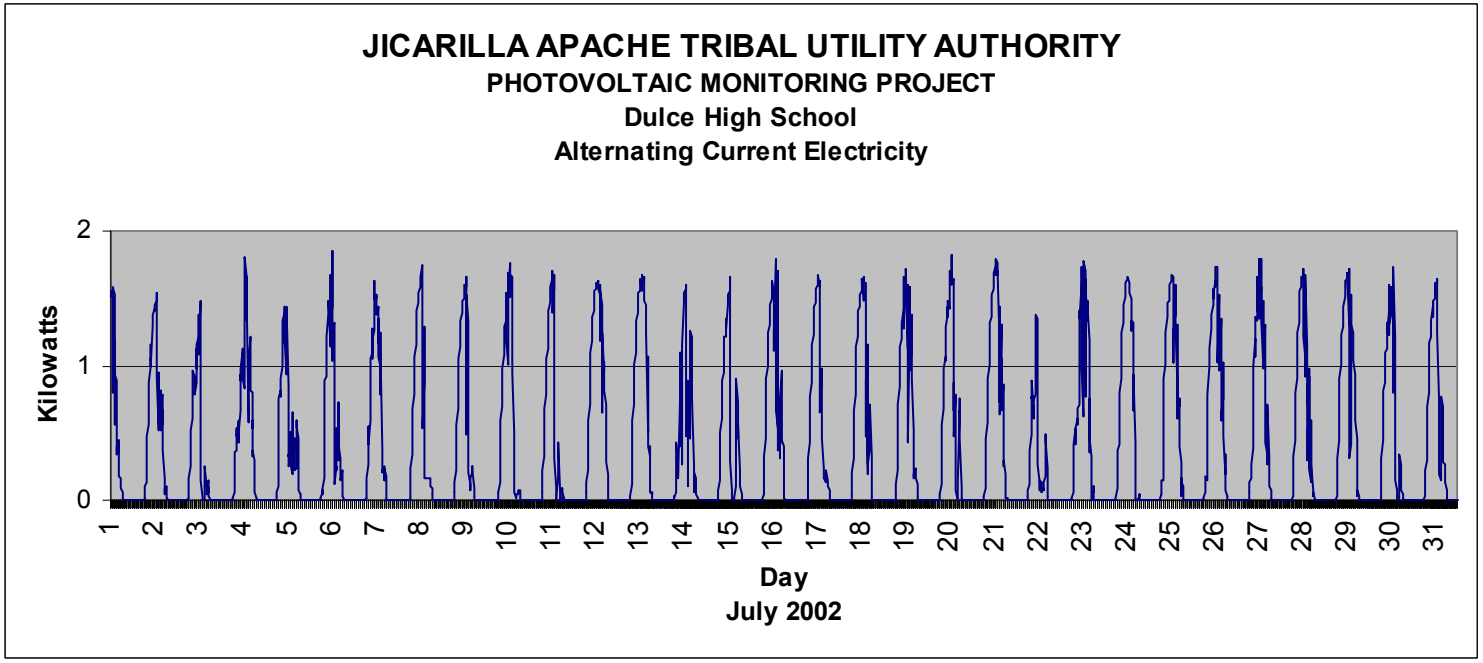




Graph-2

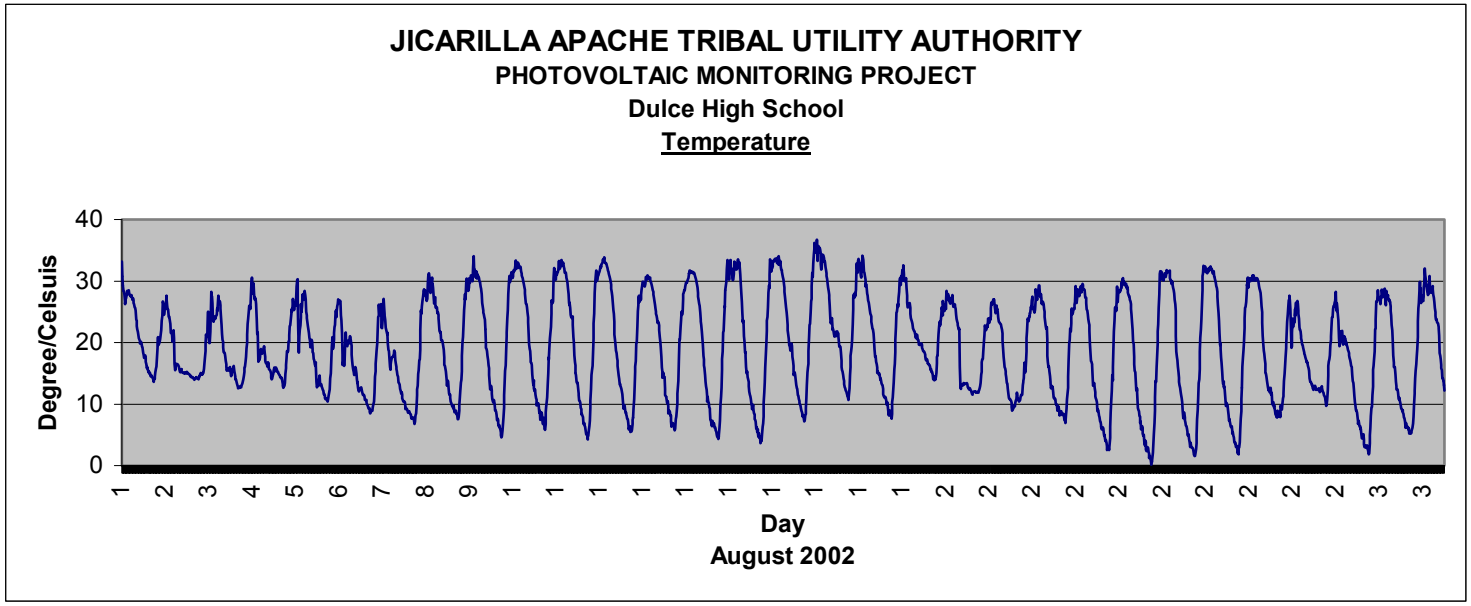
Graph-3

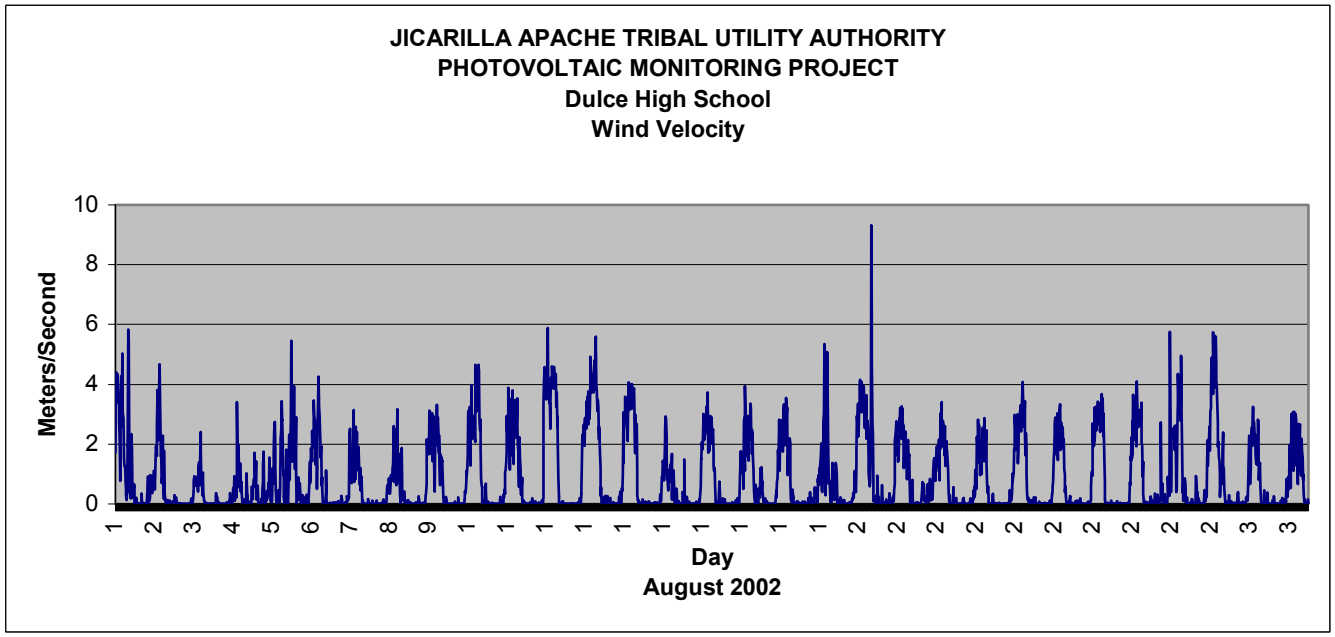




Graph-4

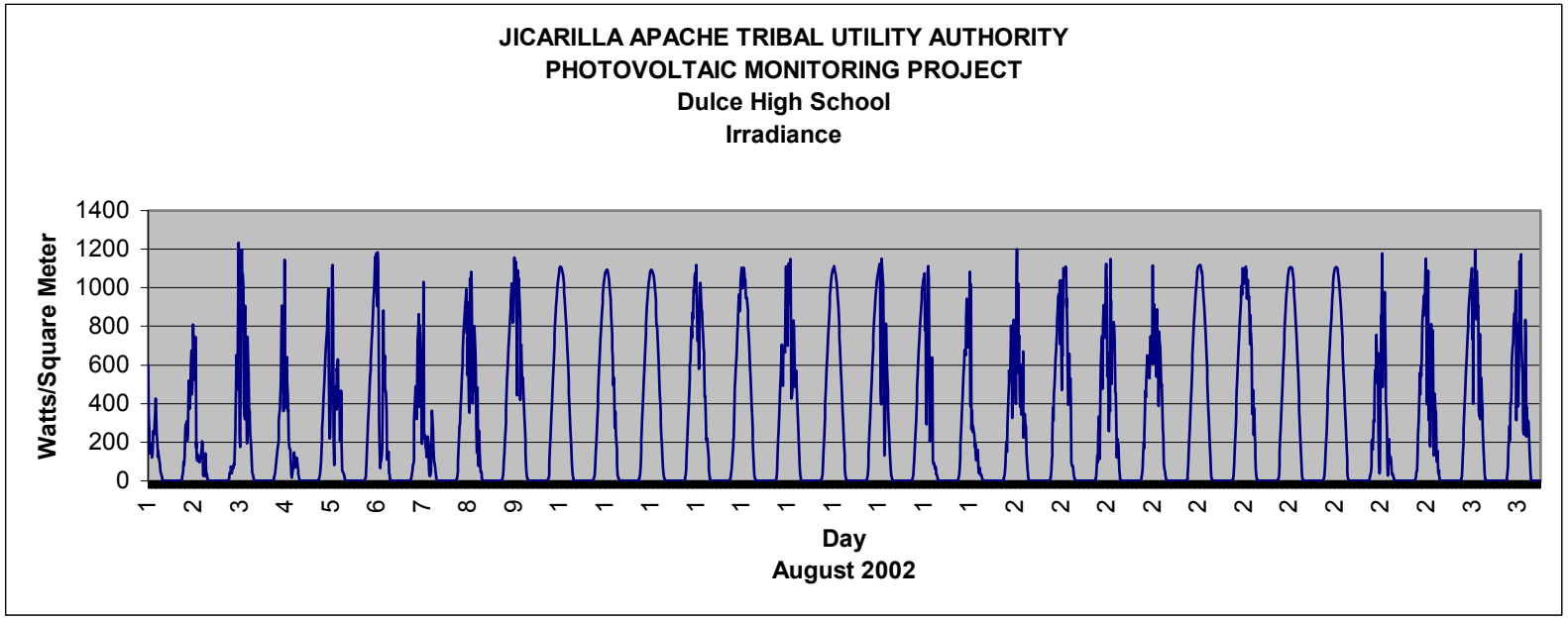
Graph-5

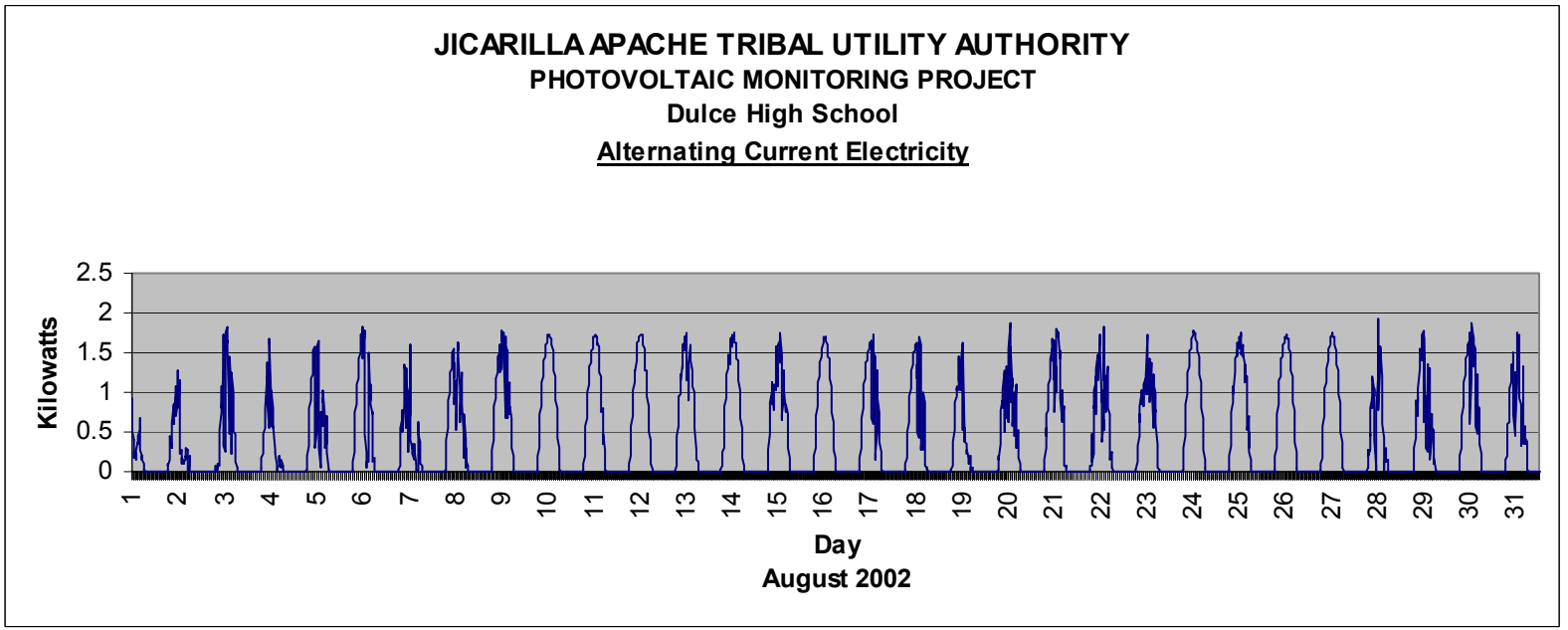




Graph-6

Graph-7





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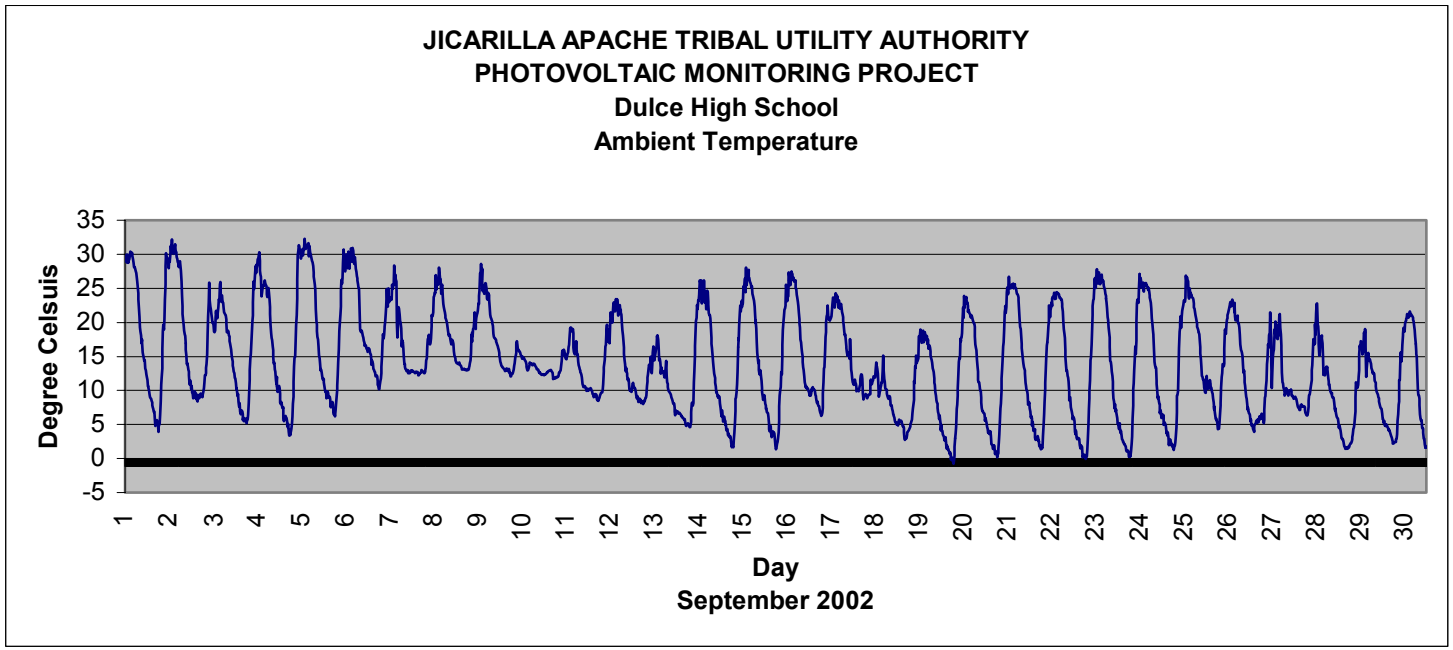
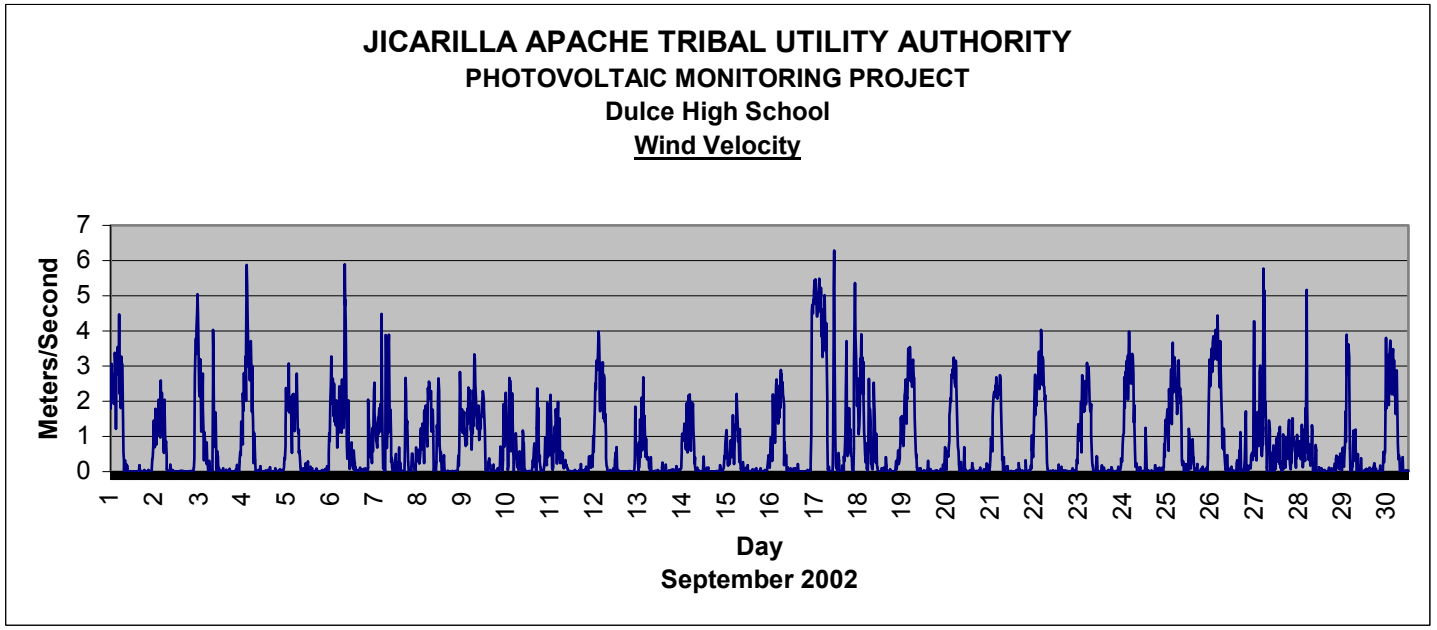
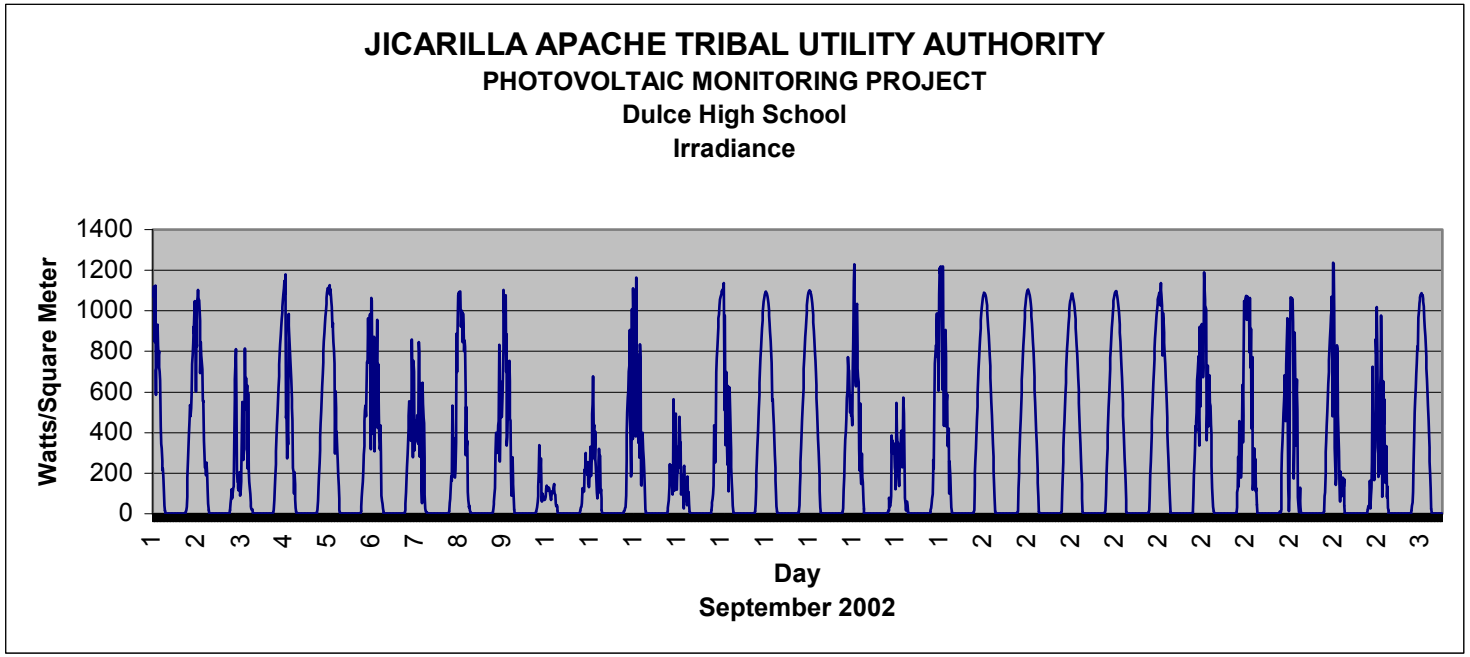
Graph-9

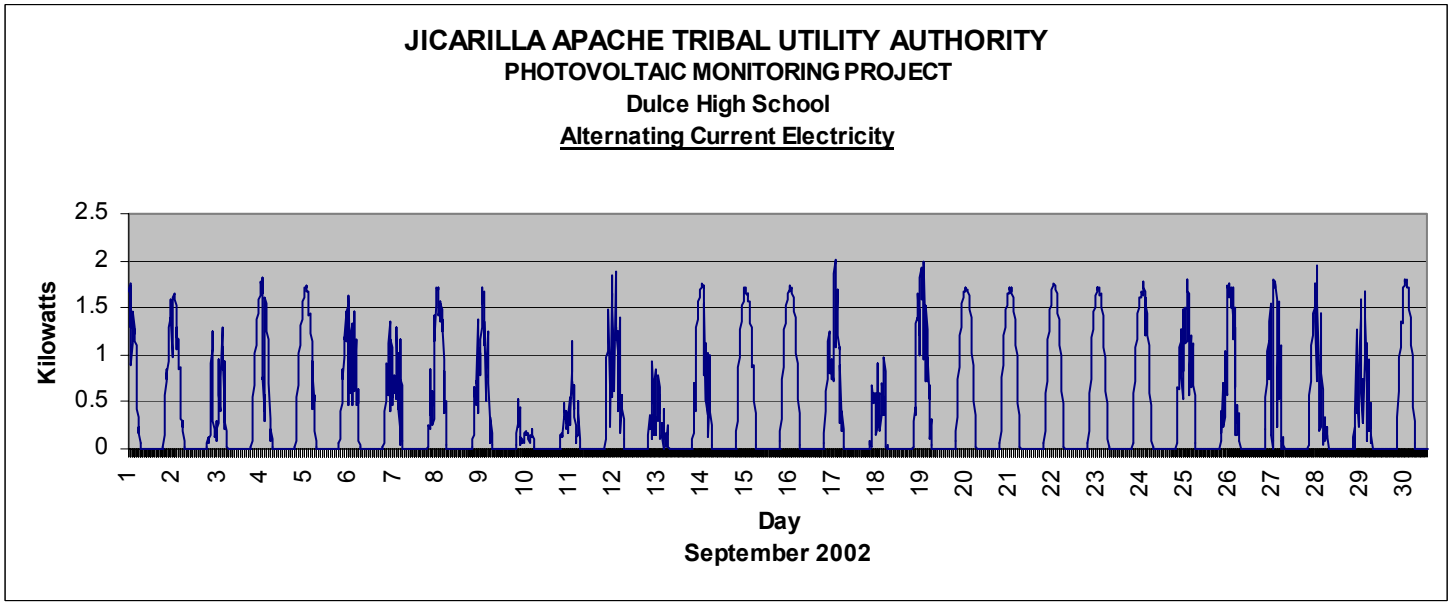




Graph-10

Graph-11





Graph-12

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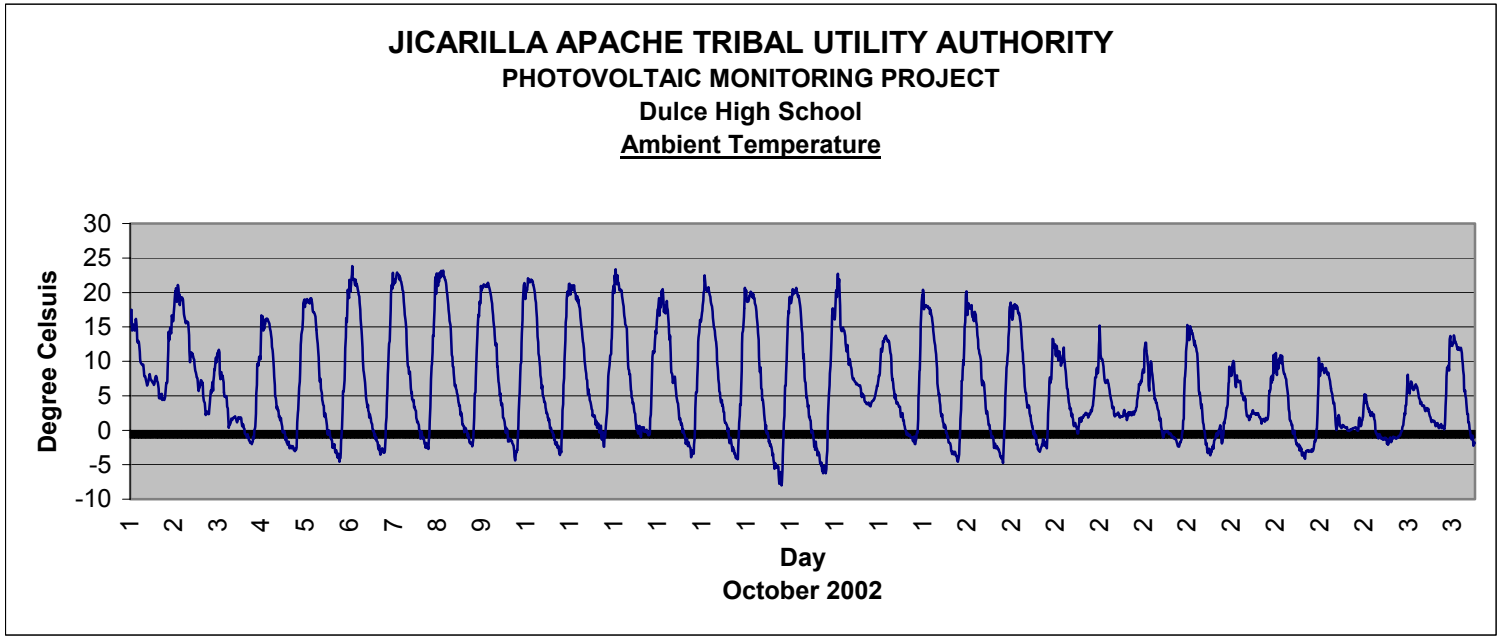
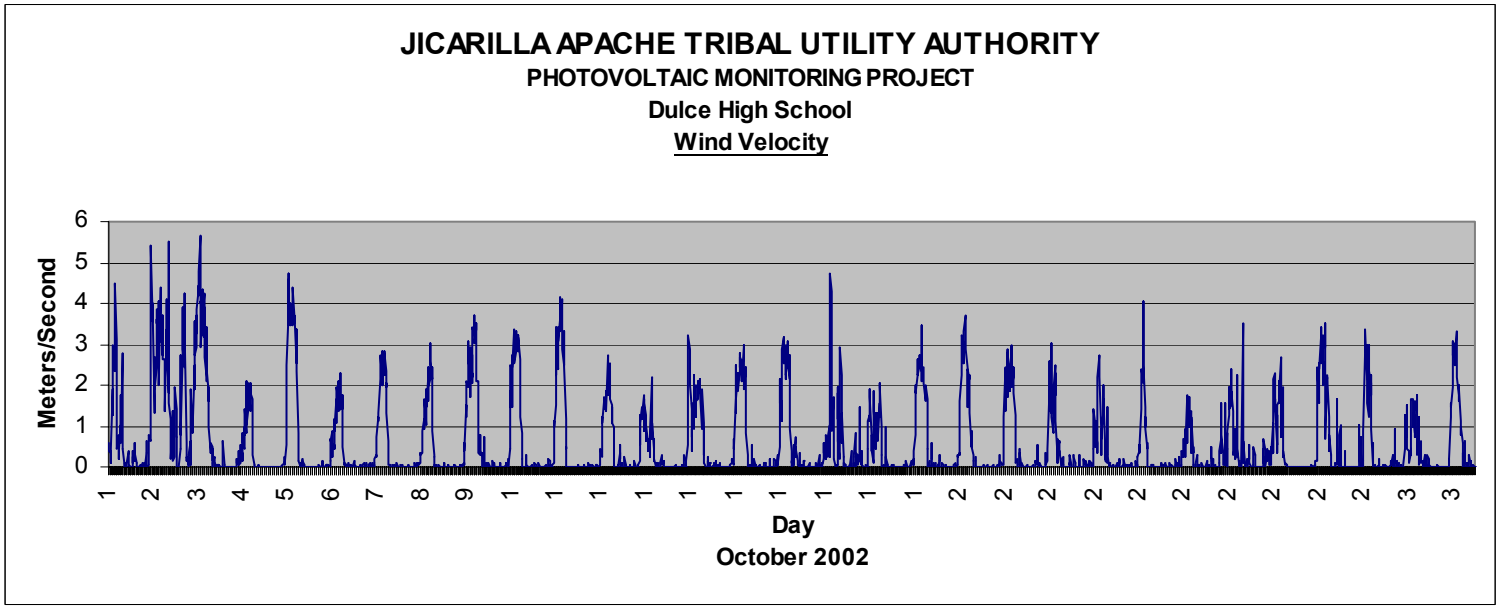
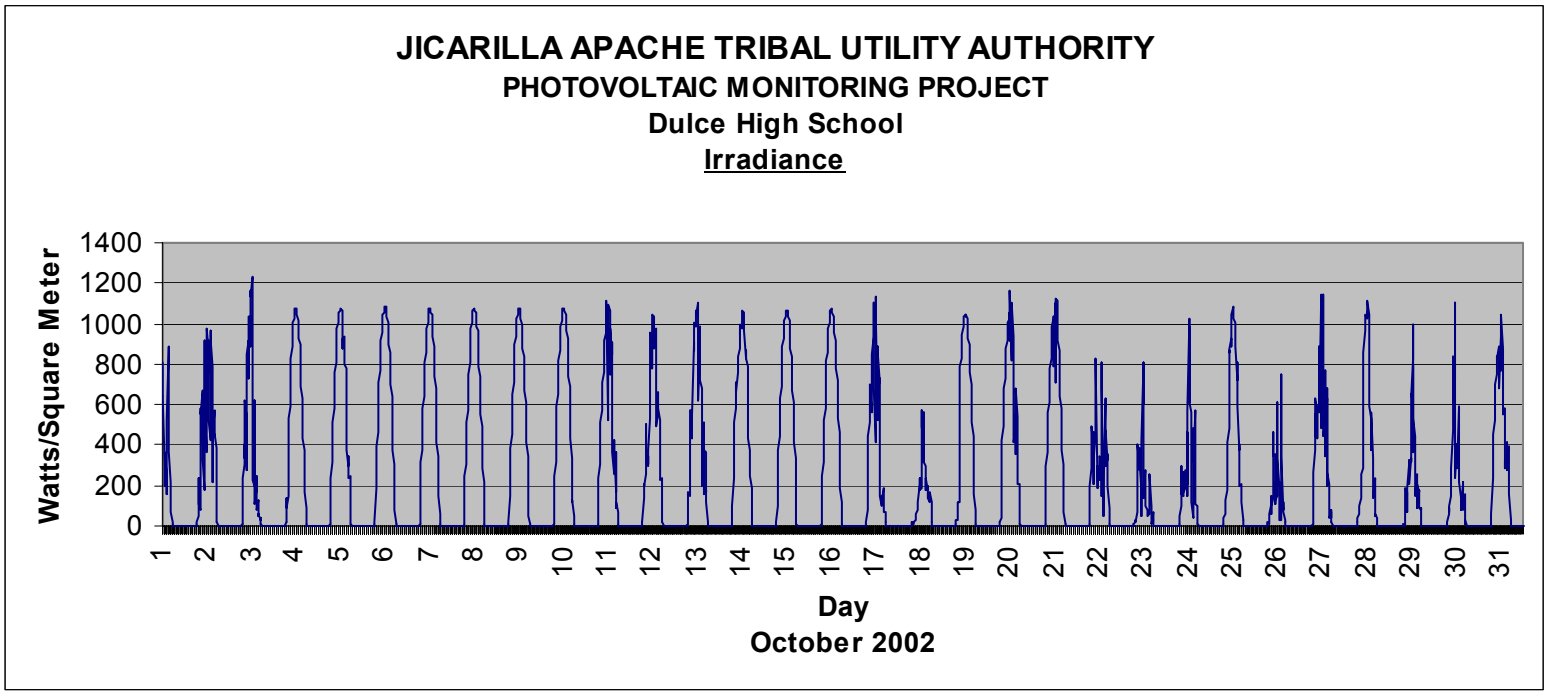
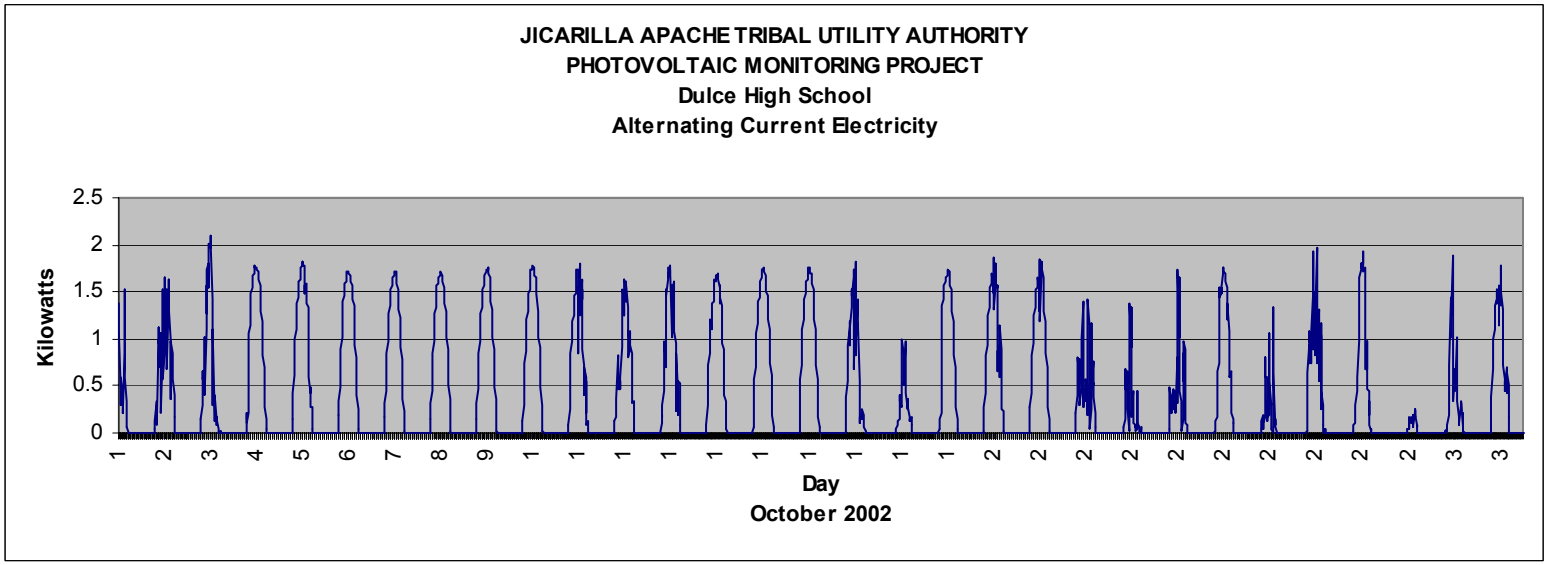




Graph-14

Graph-15





Graph-16